# MET 2700
# General Meteorology

## Units of Measurement Common in Meteorology

Goals:
Become familiar with Metric Measures
Be able to convert between units
Have a (very crude) idea of how measurements are taken

# Other References

General Introduction to Weather and Climate

- Pages xv to xvii of AS, Chapter 2 of Meteorology, & Appendix A of MSE

- Key characteristics
  - Time scales of weather and climate
  - Weather Observations
  - Common units of measurements in meteorology

# Tools of Description: Units

- Most sciences now use System International (SI) units.
- However, in the USA, most people still use English units.

| Variable | SI Units | English Units |
|---|---|---|
| Distance | meters [m] | inches, feet, miles |
| Time | seconds [s] | seconds [s] |
| Temperature | Celsius [°C] or Kelvin [K] | degrees Fahrenheit [°F] |
| Mass | grams [g] or kilograms [kg] | pounds (mass) |
| Force | Newtons [$N = kg\,m\,s^{-2}$] | pounds (force) |
| Pressure | Pascals [$Pa = N\,m^{-2}$] | inches of Mercury [inHg] |
| Energy or Work | Joules [$J = kg\,m^2\,s^{-2}$] | calories |

- See pages 436 and 437 in Stull's book.
- See pages xv–xvii in Atmospheric Sciences (on BB site)

# Time Scales of Weather & Climate

- Weather refers to short term, sometimes local characteristics.
  - The details of today or in the near future (say one week).

- Climate is based on longer term characteristics, often applied to a larger spatial scale than weather.
  - Climate describes the likelihood of various types of weather.
  - Also describes changes in the distribution of weather events

- Both climate and weather can vary a great deal over seemingly short distances.
  - For example the climate on one side of an island is often radically different than the climate of the other side.
  - Why are the climate and weather at Tallahassee different than the climate at near by Gulf Coast beaches?

# Weather Observations & Observational Techniques

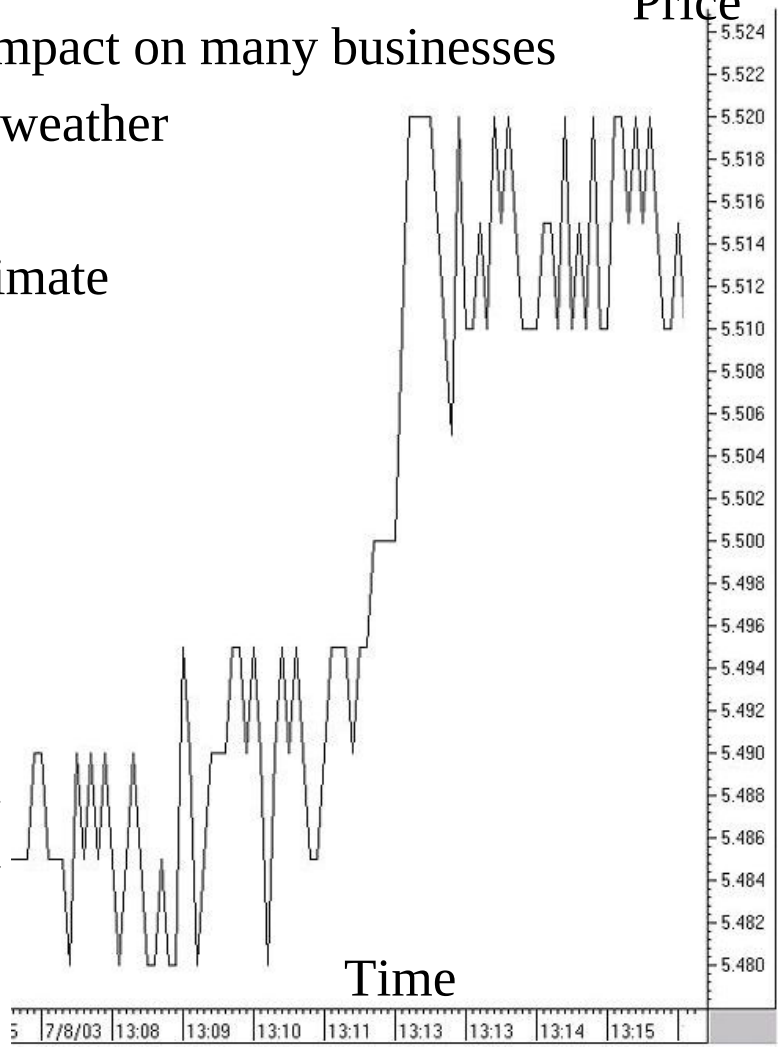
- Most people want to know the conditions that they will be experiencing:
  - Temperature
  - Humidity
  - Precipitation
  - Wind speed and direction
  - Cloud Cover (a proxy for daytime heating, nighttime cooling, or tanning conditions)
  - Visibility (critical for travel)
  - Pressure
  - The likelihood of severe weather in the foreseeable future

Graphic from *Meteorology* by Danielson, Levin and Abrams

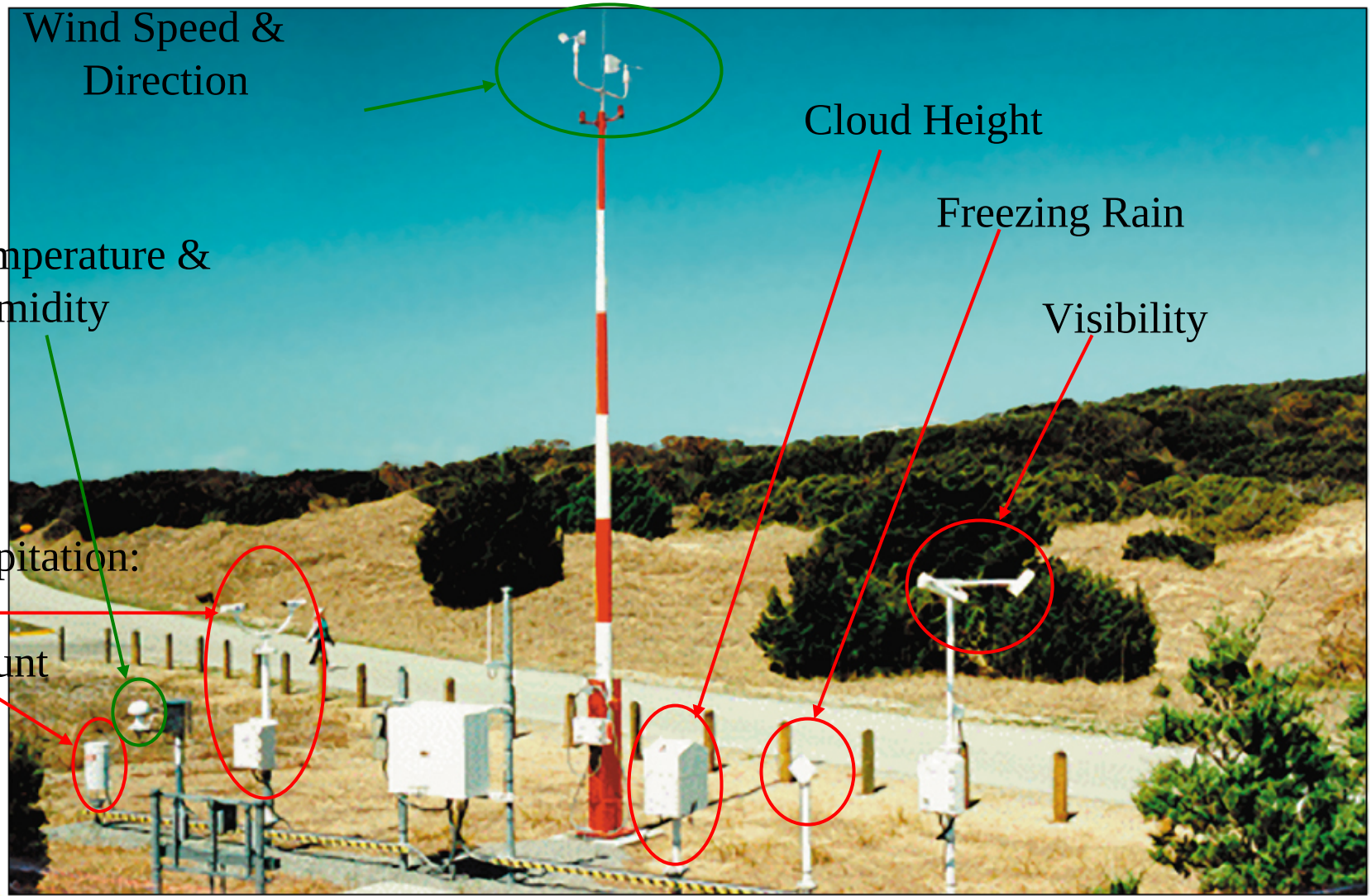
# Businesses and Weather

- Businesses are interested in similar observations and forecasts
- Severe weather and climate have a great impact on many businesses
  - The ability to ‘work’ is influenced by weather
    - In some case by ocean currents
  - The cost of energy is influenced by climate
  - Ease of transportation
  - Agricultural productivity
  - Damage Mitigation
  - Reinsurance

On the 8th at 1806GMT, the Special Tropical Statement declaring Tropical Storm Claudette hit the wire. The attached file shows the tick by tick natural gas prices. Within 3 minutes, the price jumped 10 cents.



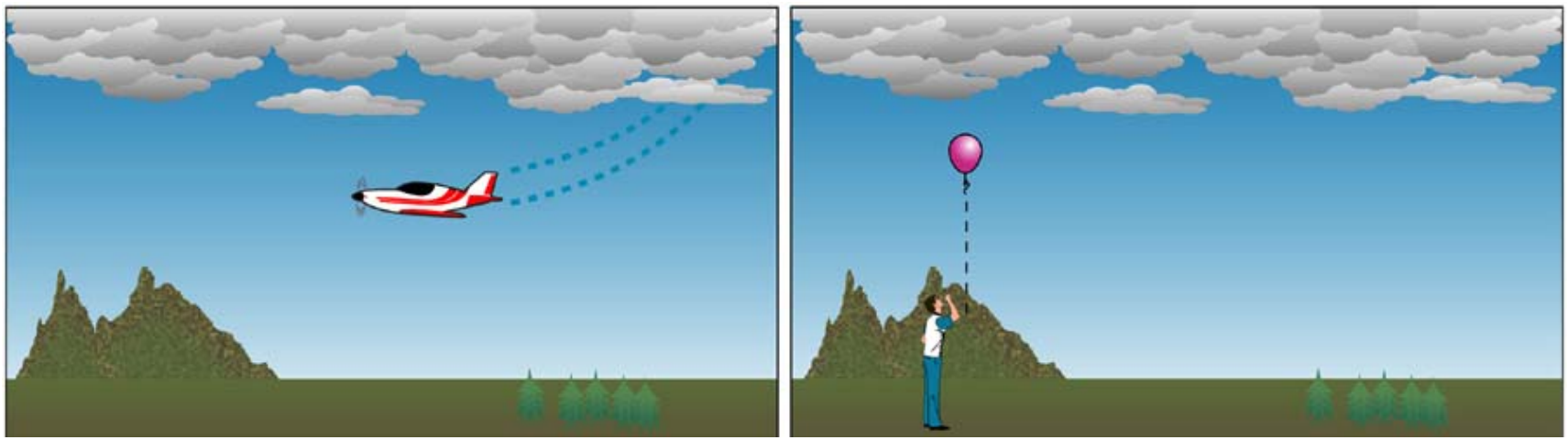
# ASOS Observing Unit




Graphic from *Meteorology* by Danielson, Levin and Abrams

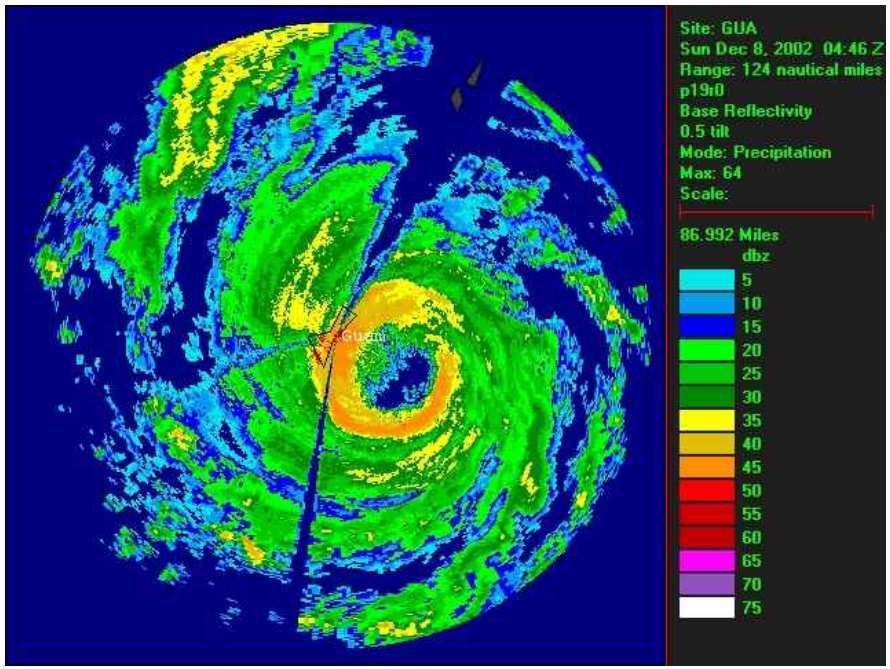
# Upper Air Observations

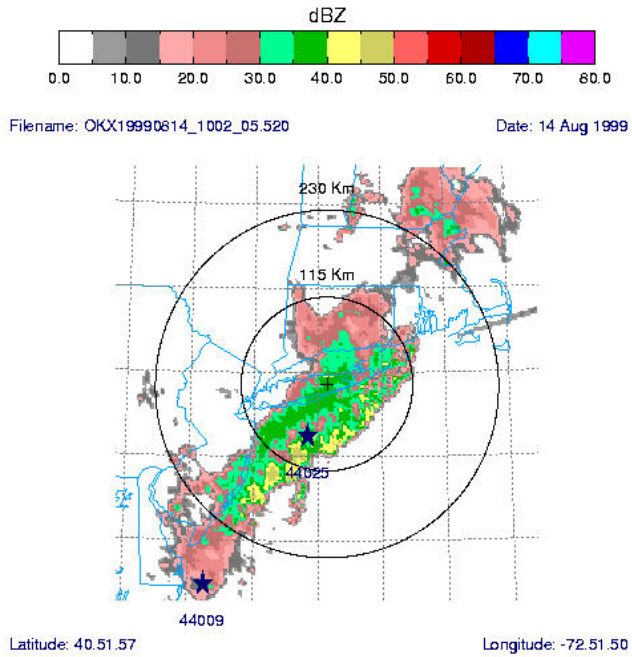
- From
  - Weather balloons
  - Aircraft
  - Cloud motion



Graphic from *Meteorology* by Danielson, Levin and Abrams

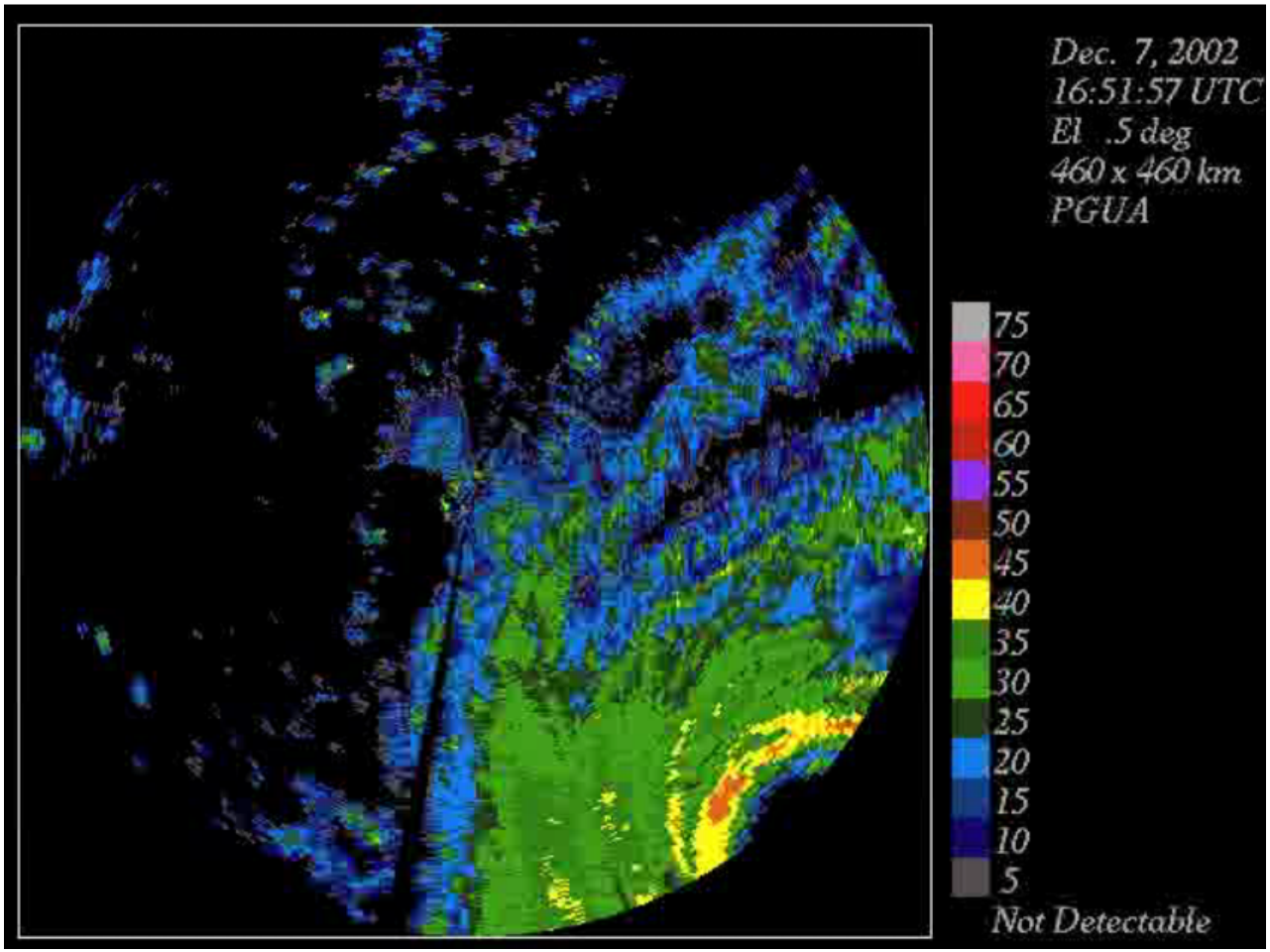
# Weather RADAR



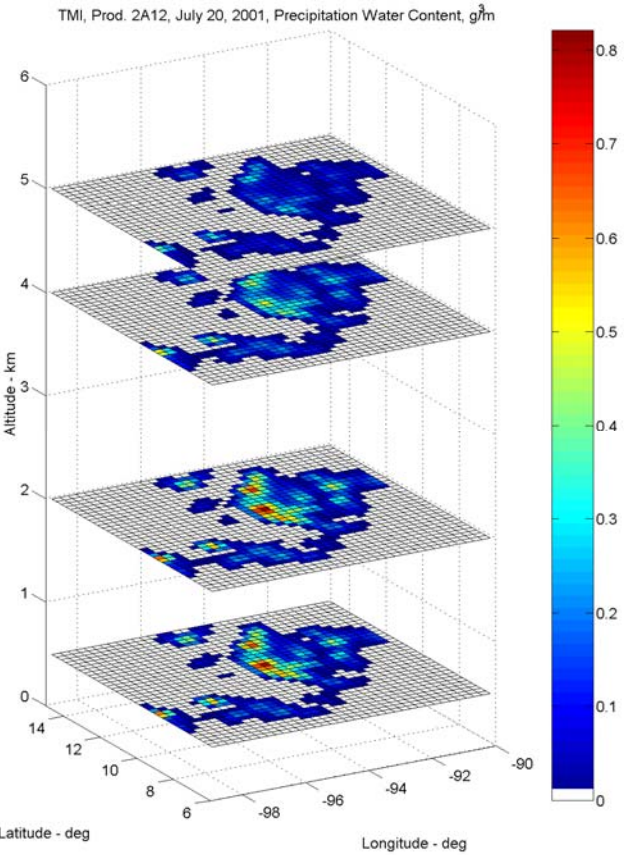

- Weather radars provide far greater spatial coverage with much greater sampling. Signatures of severe weather can be remotely sensed.

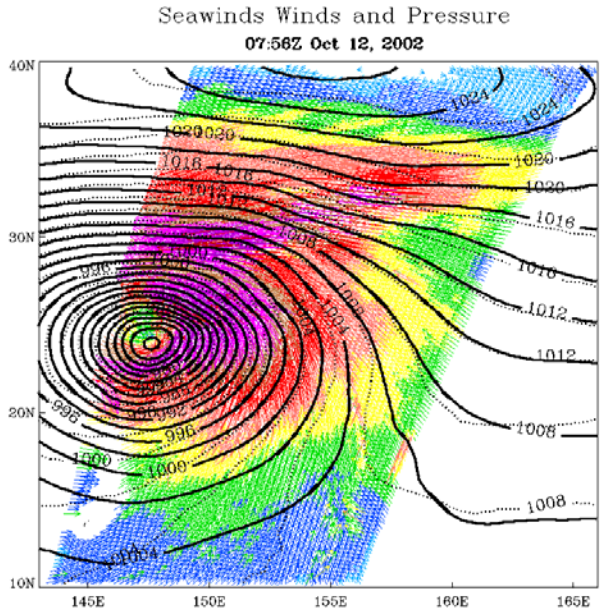
# Super Typhoon PONGSONA

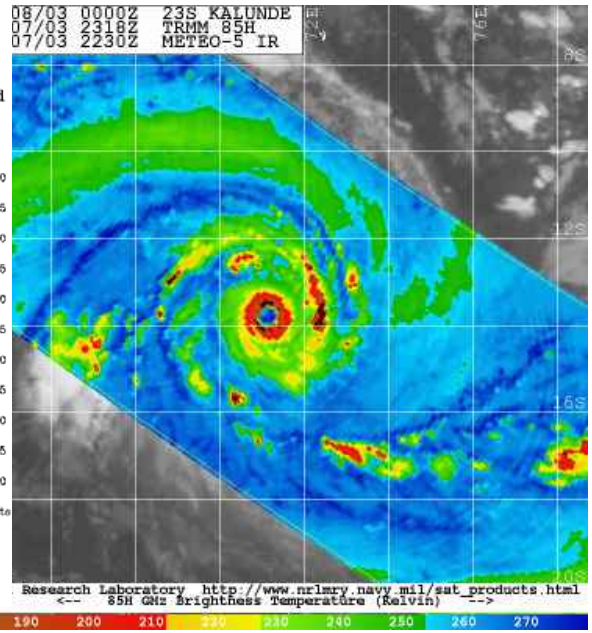



- Evolution of Super Typhoon Pongsona can easily be seen in NEXRAD radar (at least as long as the radar is working).

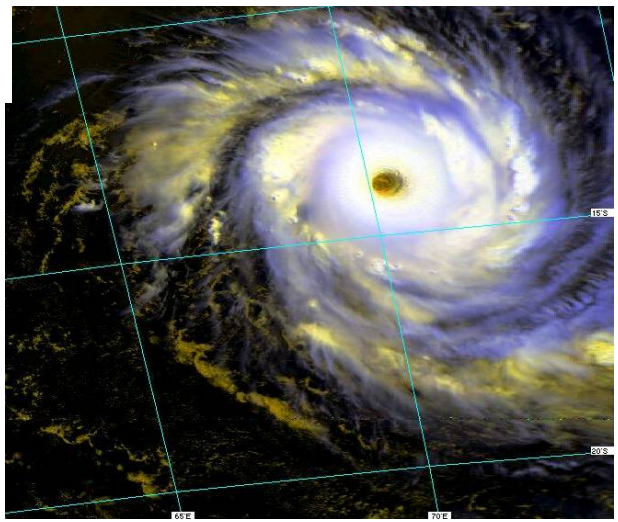
# Satellites

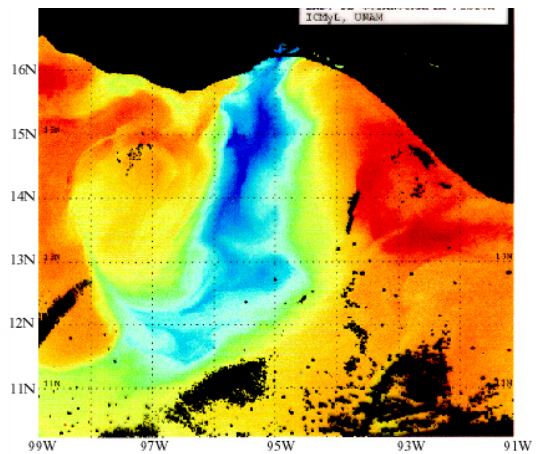

TMI, Prod. 2A12, July 20, 2001, Precipitation Water Content, g/m3
Altitude - km
Latitude - deg
Longitude - deg


Seawinds Winds and Pressure
07:56Z Oct 12, 2002
Wind Speed


08/03 0000Z 23S KALUNDE
07/03 2318Z TRMM 85H
07/03 2230Z METEO-5 IR
Research Laboratory http://www.nrlmry.navy.mil/sat_products.html
85H GHz Brightness Temperature (Kelvin)


TERRA MODIS 2001-04-03 1613-1625 UTC Bands 010403 HKM: Bahamas and Cuba




16N
15N
14N
13N
12N
11N
99W
97W
95W
93W
91W

# Observation Times

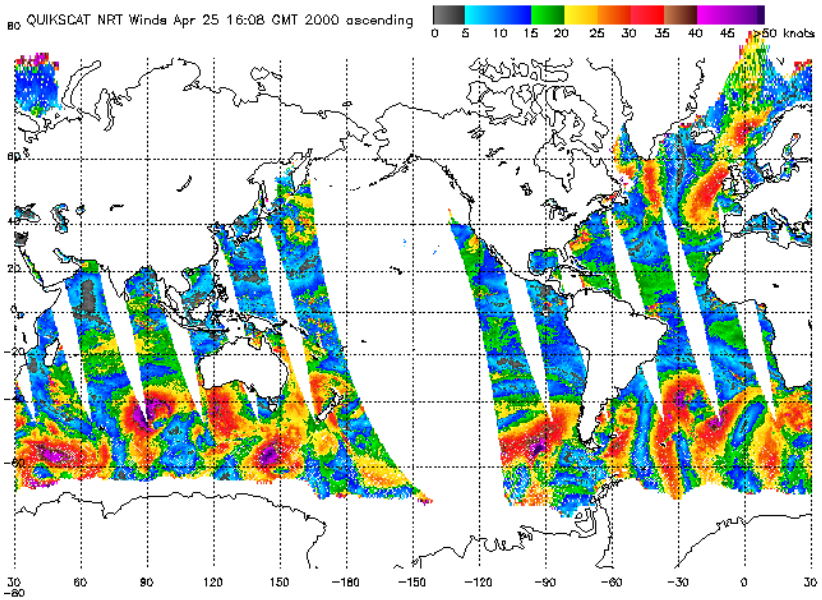
- Local times (time changes can be confusing)
  - Times differ from time zone to time zone
  - Changes for daylight savings time
    - Indiana has three distinct regions
      - Time zones of nearby cities (Chicago & Cincinnati)
      - Uses daylight savings or does not use it
- A globally uniform system
  - Times are reported in Greenwich Mean Time (abbreviated as GMT or Zulu (Z))
    - The time at one location on the globe, without daylight savings

# Remotely Sensed Observations

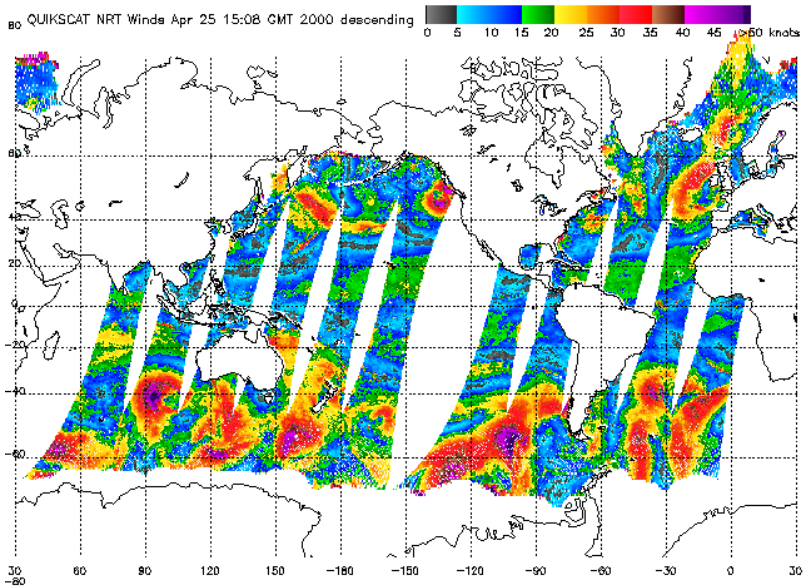
- Satellites are RADARs tend to measure in electromagnetic units
  - Volts
  - Amps
  - Power of signal
- These are not geophysical units, and for weather purposes are often converted to geophysical units prior to use
- The conversions depend on assumptions that are rarely idea
  - There are random errors associated with all observations,
  - Remotely sensed observations can have substantial regional biases

# SeaWinds Daily (22 hour) Coverage

Ascending Node




Descending Node



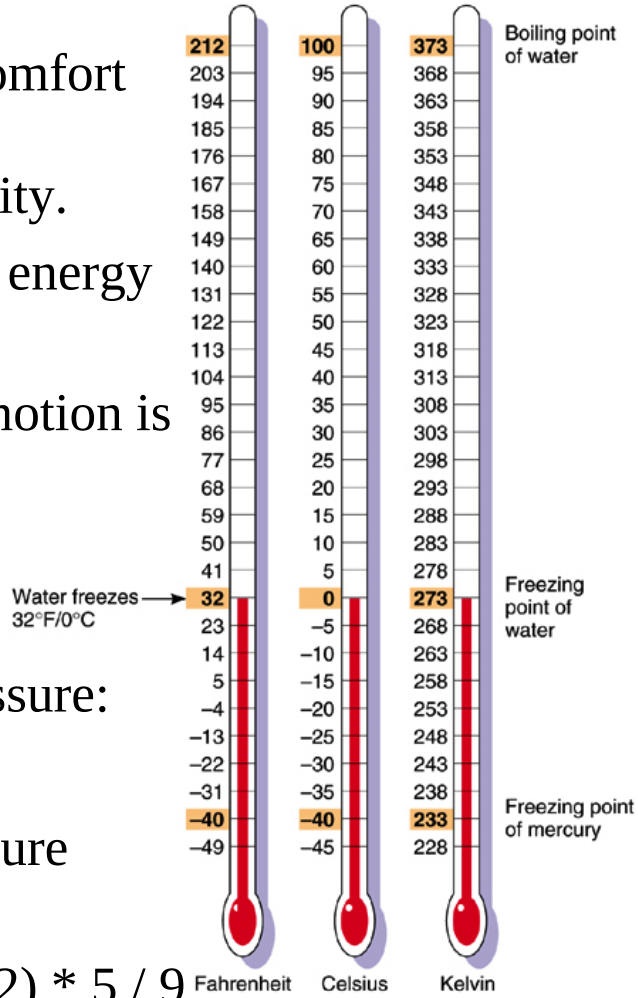

Jan. ??, 2000

From Paul Chang (NOAA/NESDIS): http://manati.wwb.noaa.gov/quikscat/

Satellite take observations at times other than 00Z, 06Z, 12Z, and 18Z!

# Temperature

- How hot or cold is an item (e.g., a parcel of air)?
  - Typically, hot and cold are relative to a level of comfort
    - This common definition is not quantitative
  - Temperature is a quantitative measure of this quality.
    - Temperature is an indication of the amount of energy (per unit mass) stored in a material.
    - At absolute zero, the energy from molecular motion is zero
      - Absolute zero equals
        0K = -273.15°C = -459.67°F
    - Freezing point of water at 1 atmosphere's pressure:
      - 273.15K = 0°C = 32°F
    - Boiling point of water at 1 atmosphere's pressure
      - 373.15K = 100°C = 212°F
  - Degrees C = degrees K – 273.15 = (degrees F – 32) * 5 / 9




Graphic from *Meteorology* by Danielson, Levin and Abrams

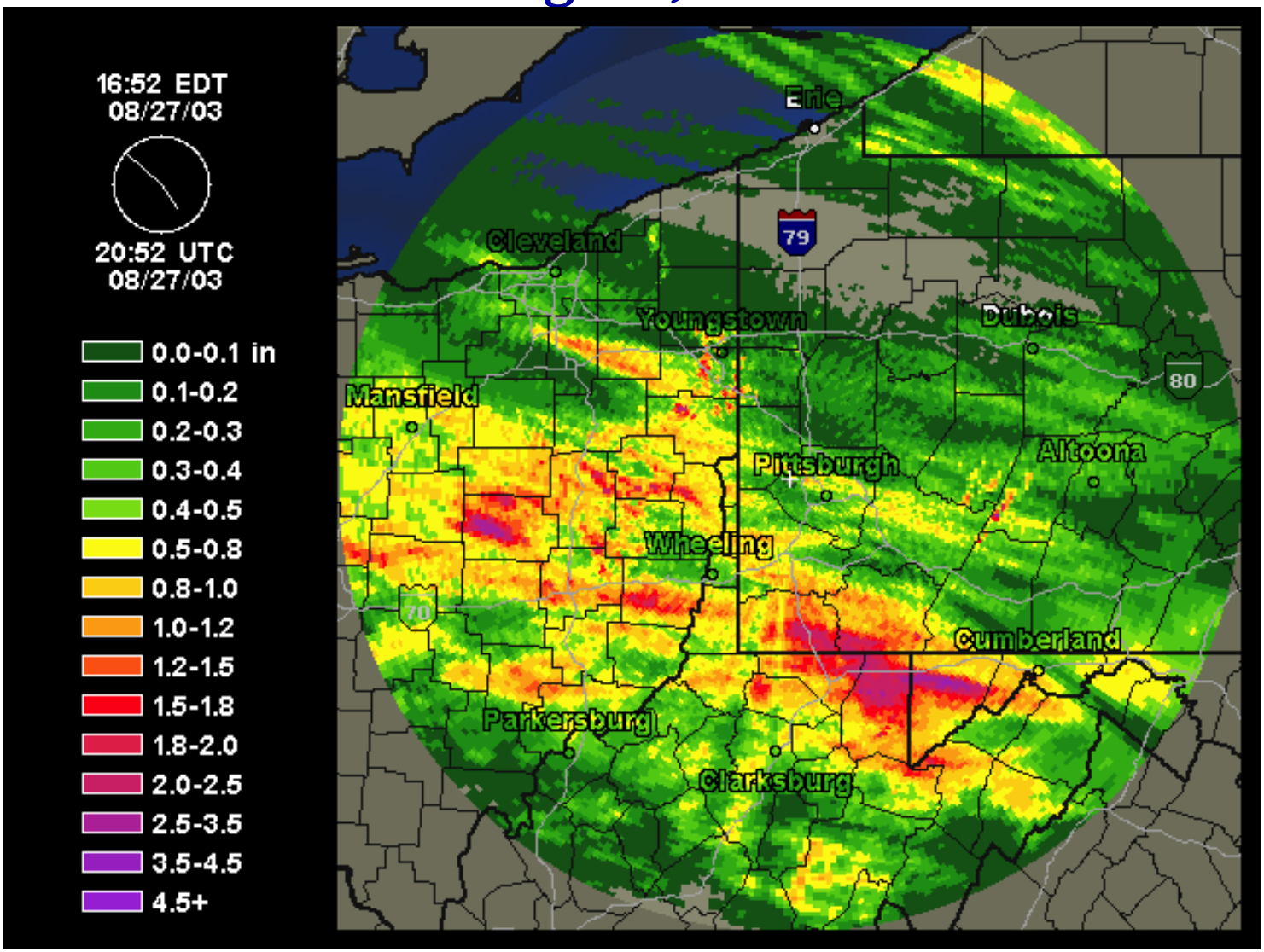
# Humidity

- Humidity is a measure of the amount of **water vapor** in the air.
  - Water vapor is the gaseous form of water
  - Humidity is not a measure of the rate of precipitation
- Combined with temperature, humidity can be used to determine the **Heat Index**, which indicates how hot it feels.
- Humidity modifies
  - the density of air
  - the amount of energy in a parcel of air
  - The rate at which energy is transferred from a water surface to the neighboring air
- Humidity is usually measured as a percentage of the amount of water vapor needed to saturate the air at the observed temperature.
  - More on this in later lectures – not a trivial concept.

# Precipitation

- Precipitation can be liquid (rain), solid (snow and hail), or a combination of the two (wet snow)
- Precipitation is measured in terms of a rate (e.g., mm/hr, inches/hr)
  - Surface stations typically report 6 hour and 24 hour averages.
- The depth of snow is typically 12 to 20 times the depth of the equivalent mass of water.
- Precipitation rates can be measured by collecting the precipitation in a bucket or rain gauge, by optical or sonic techniques, and through remote sensing (RADAR or satellites)

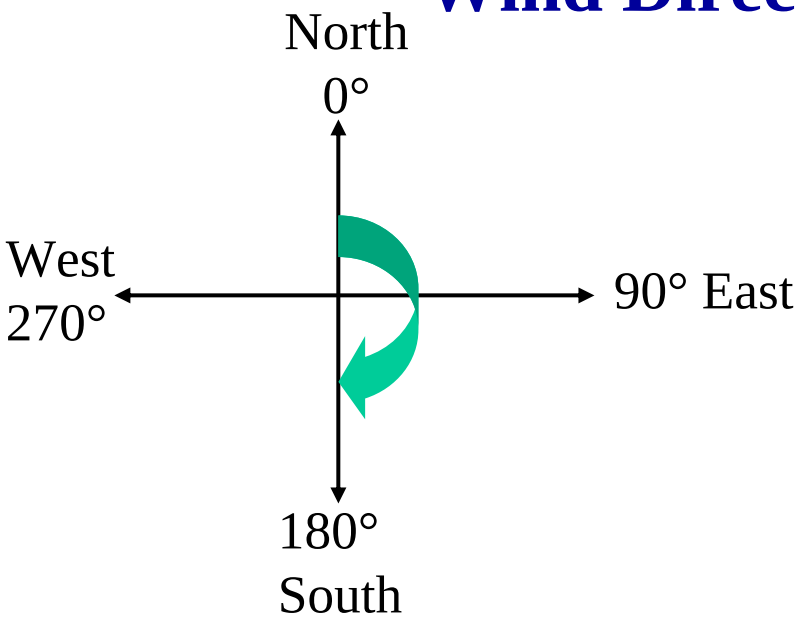
# Accumulated NEXRAD Precipitation
# Aug. 28, 2003



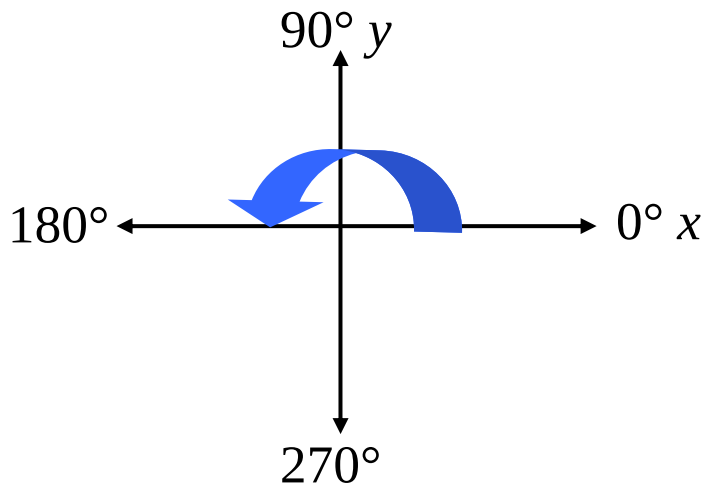
# Wind Speed and Direction

- Wind speed is the speed at which air moves, typically relative to the earth's surface.
  - Typical units are m/s, miles per hour, and knots (nautical miles per hour).
  - 0.514 m/s = 1 kts = 1.15 mph.
  - Units of direction are degrees, clockwise, relative to North.
    - Meteorological directions are the direction from which the wind is moving.
- Wind direction can be measured with wind vanes.
  Wind speed can be measured by the impact it has on objects (typically rotating cups or propellers, or water waves).
- Wind speed and direction distributions are key characteristics for designing structures to withstand winds.
- Combined with temperature, the wind chill factor can be determined, which indicates how cold it feels.

# Wind Direction Convention




**Meteorological Convention**




**Mathematical Convention**

- Meteorological directions are the direction TO which the wind is moving.
- Oceanographic directions are the directions FROM which the wind is moving (180° different from the meteorological directions).
- If you are doing trig, use a direction of 270° minus meteorological direction

# Cloud Cover

- The type of cloud
  - Its shape
  - its height, and
  - its coverage

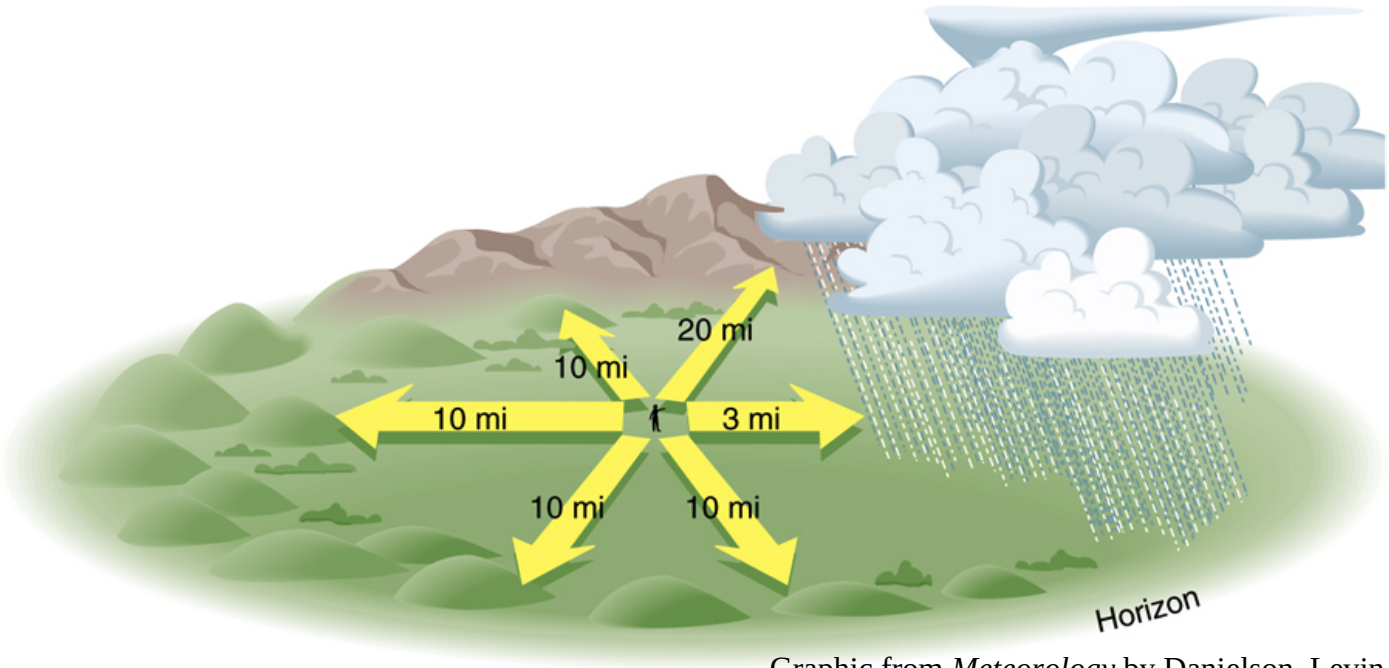
  are useful indications of atmospheric characteristics, and in many case can be used to make short term weather forecasts.

- Cloud motion is an indication of the direction from which later weather will be coming.

# Visibility

- Visibility is critical for transportation applications
  - Airplanes cannot take off if the visibility is less than a threshold
  - Fog on highways is the cause of many multi-vehicle accidents

- Visibility can also be used to estimate the rain rate

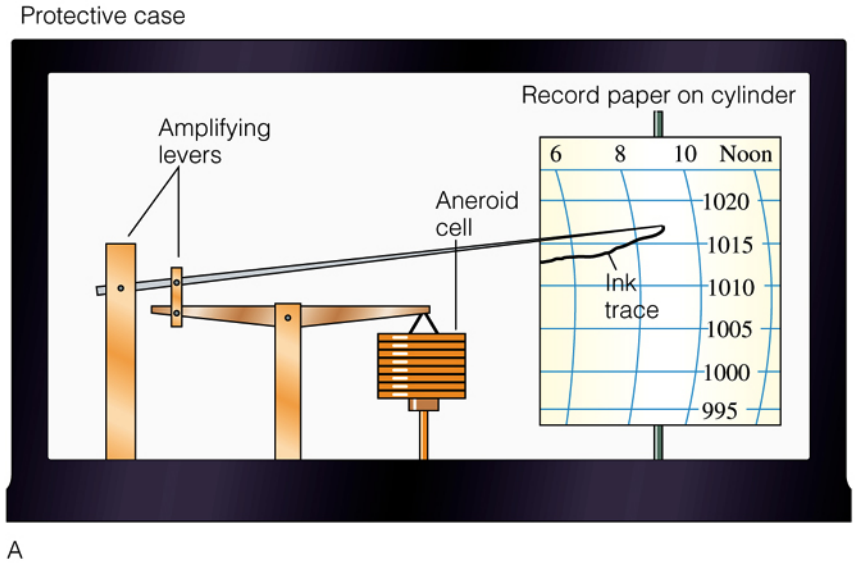



Graphic from *Meteorology* by Danielson, Levin and Abrams

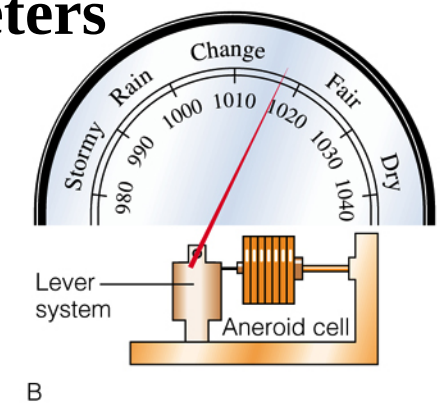
# Pressure

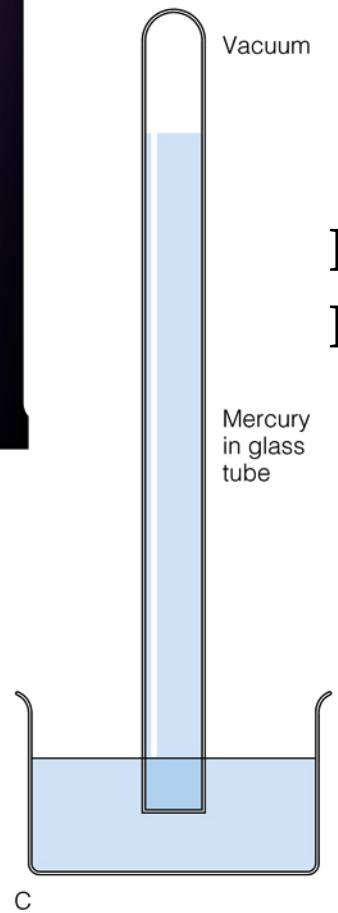
- Atmospheric Pressure is a measure of the force of the atmosphere per unit area.
- The surface pressure is often adjusted to sea level
- Typical units are Pascals (Pa), kiloPascals (kPa), millibars (mb), millimeters of Mercury (mmHg), and inches of Mercury (inHg)
  - 1 kPa = 1000 Pa = 10 mb = 7.6 mmHg = 3.0 inHg
  - Average surface pressure is 101.325 kPa.
  - Average sea level pressure is 1.6 kPa larger. Why?
- Pressure ($P$), changes in pressure with time ($\partial P/\partial t$), and changes in pressure with distance (i.e. pressure gradients, $\nabla P = (\partial P/\partial x, \partial P/\partial y)$ ) are good indicators of current and future weather.

# Measurements of Surface Pressure




## Aneroid Barometers



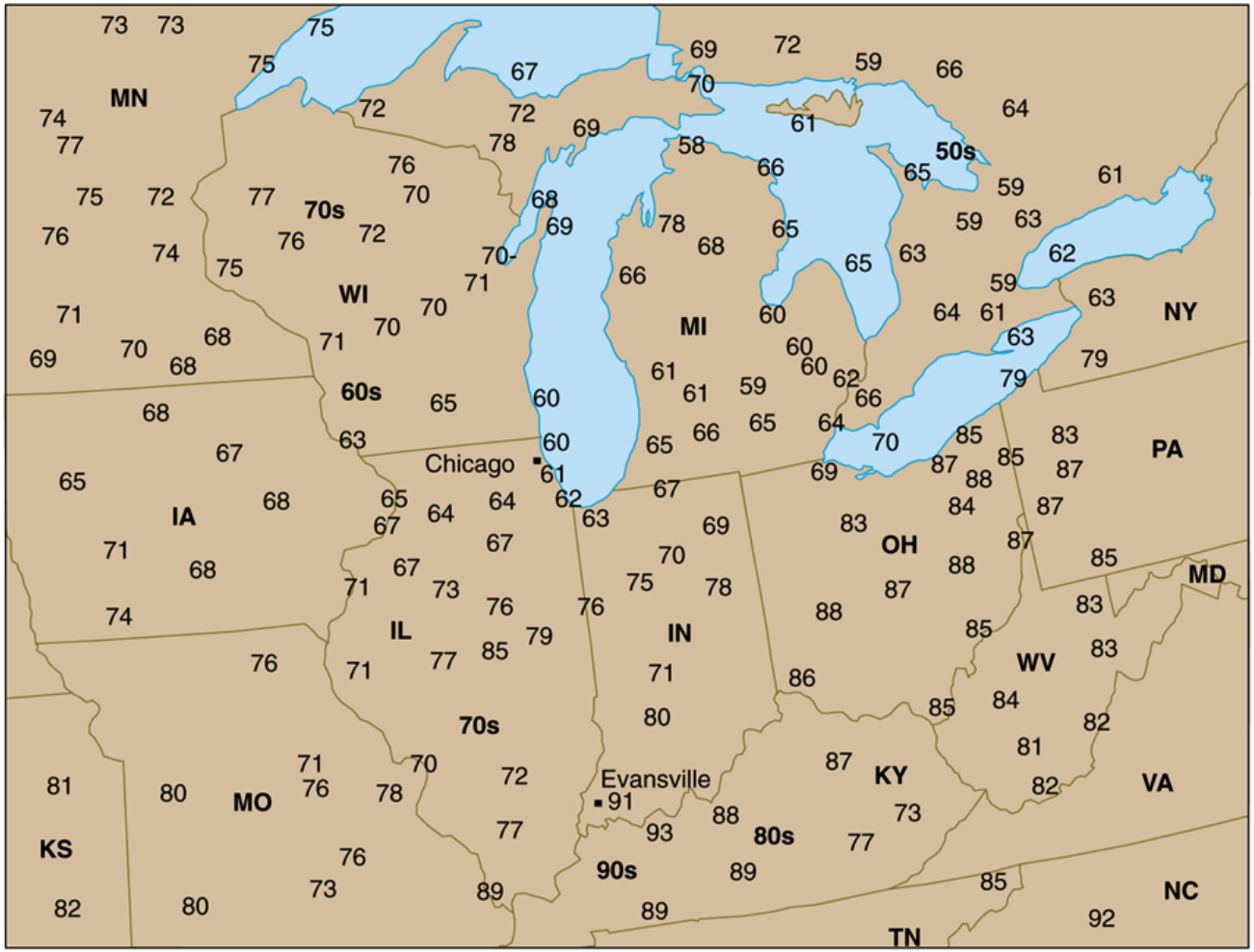




## Mercury Barometer

Source: Donald J. Conte, et al.,*Earth Science*, 2nd ed. Copyright 1997 McGraw-Hill Company, Inc., Dubuque, Iowa. All Rights Reserved. Reprinted by permission.

Graphic from *Meteorology* by Danielson, Levin and Abrams

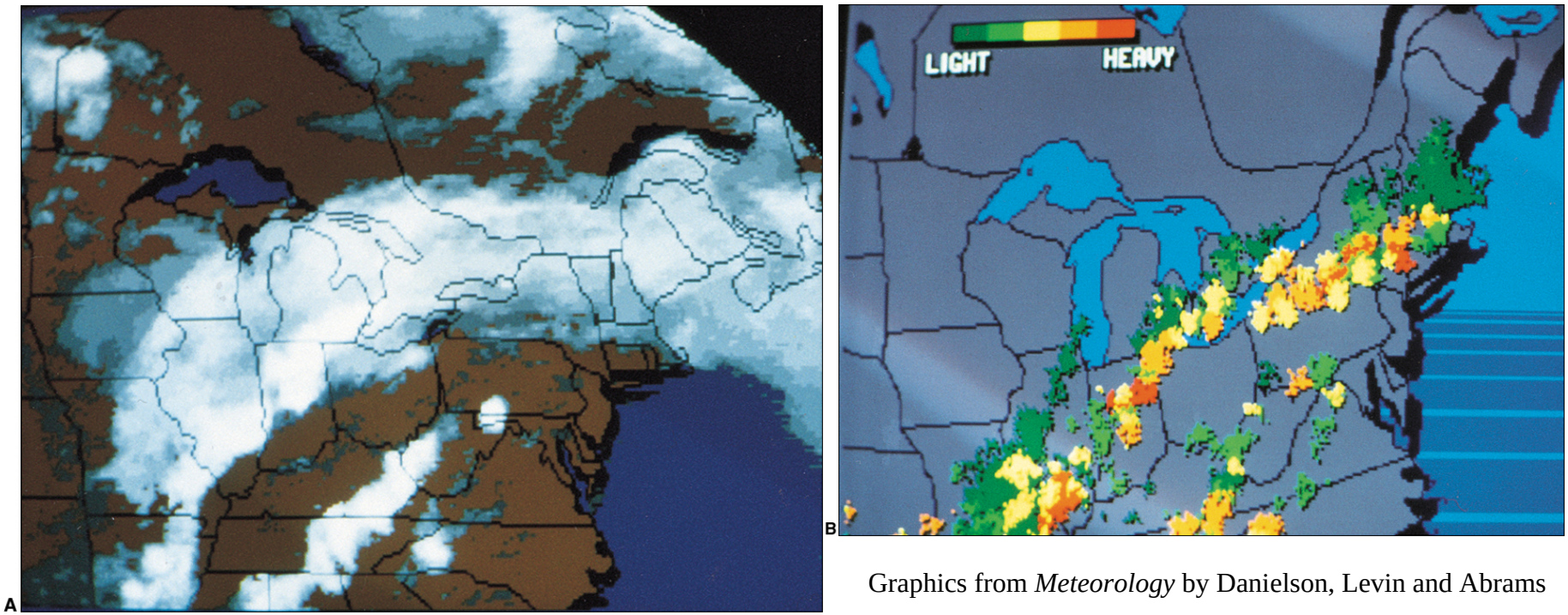
# Spatial and Temporal Characteristics




- Temperature can vary considerably over tens of kilometers and several hours
- Rain can vary greatly over 100s of meters and minutes

Graphic from *Meteorology* by Danielson, Levin and Abrams

# Remotely Sensed Images for 22Z (same time as the previous map)

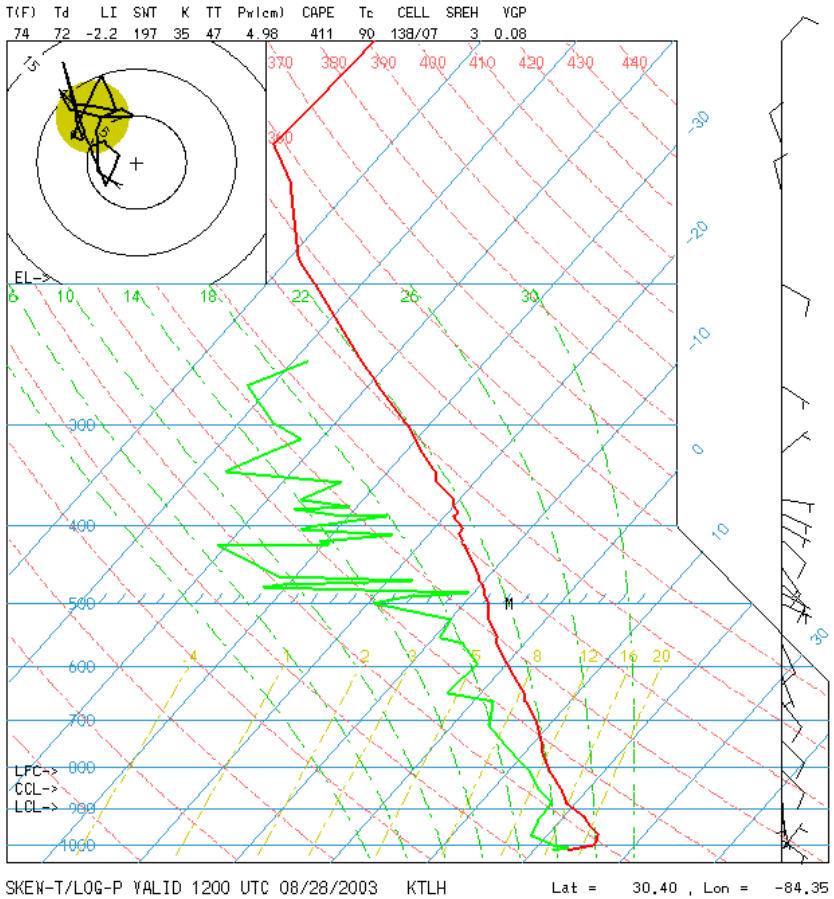


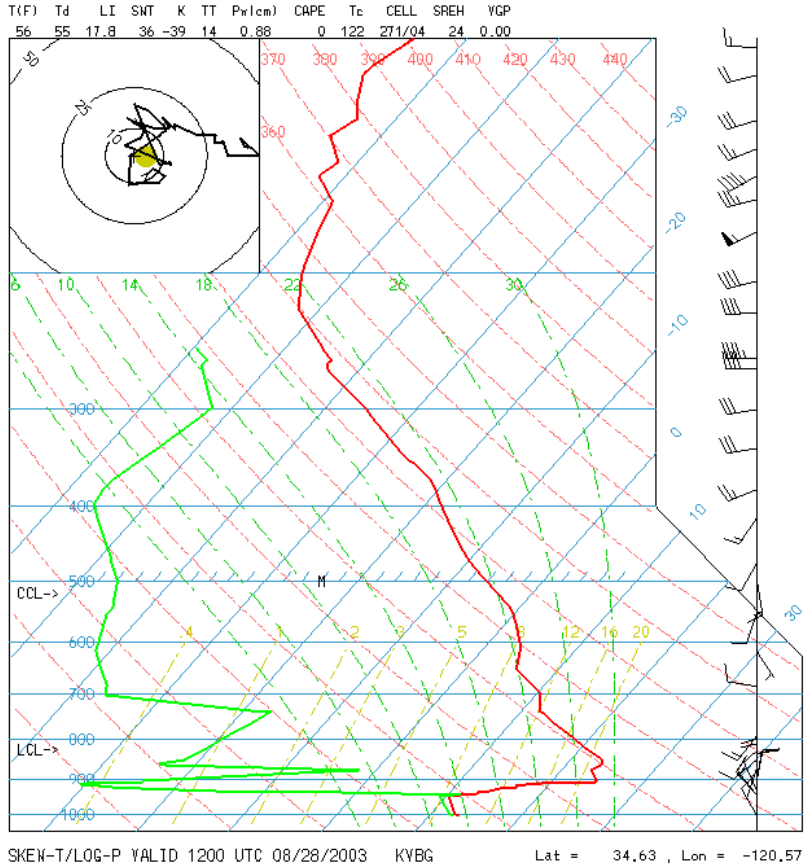

Graphics from *Meteorology* by Danielson, Levin and Abrams

- Satellite images show regions of cloudiness (and many more things)
- Weather radar shows areas of precipitation

- Is this structure associated with any features on the previous map?

# Temperature and Moisture Profiles



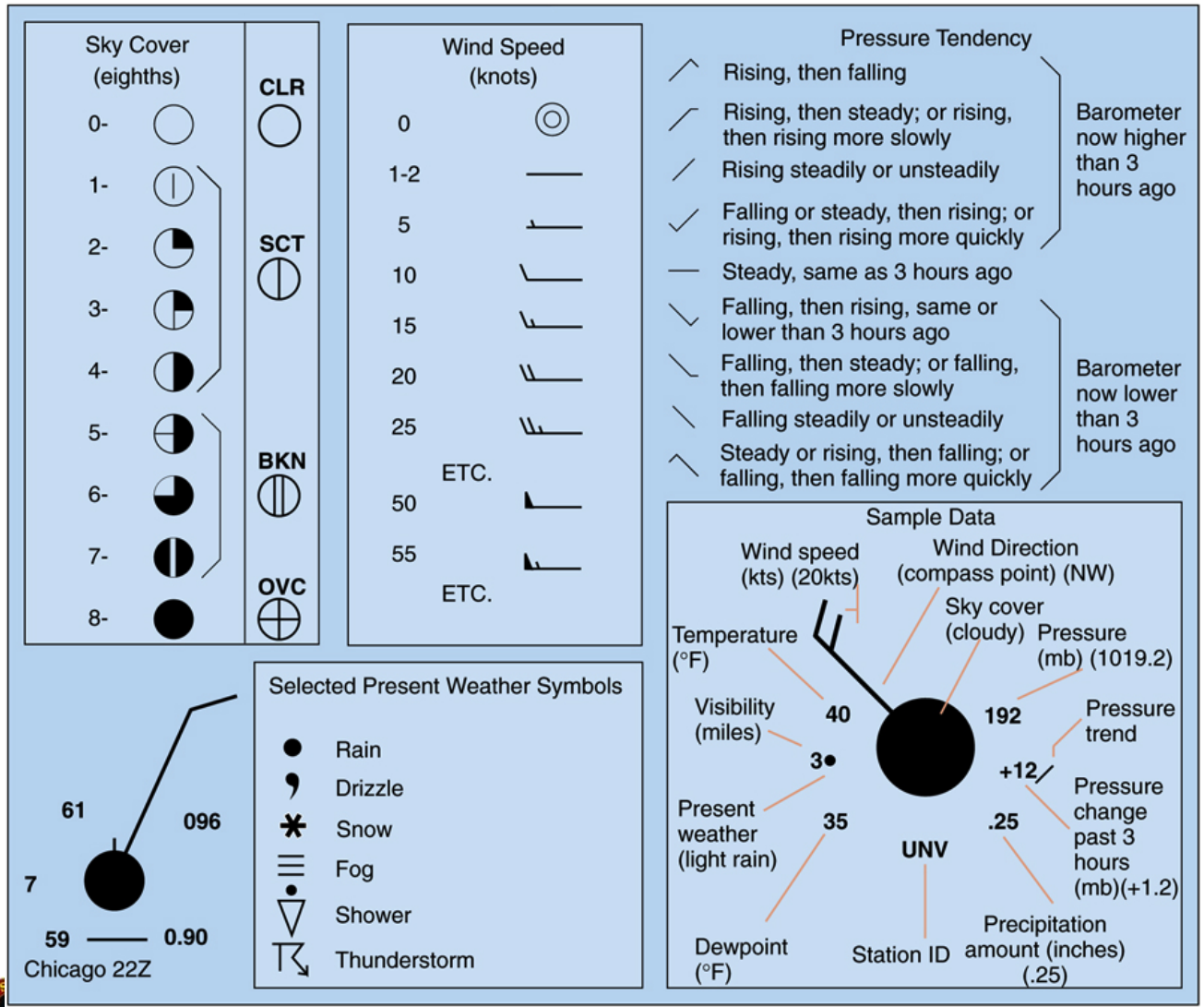

Tallahassee (TLH)

August 29, 2003

Is this station near TLH?

Example from www.rap.ucar.edu/weather

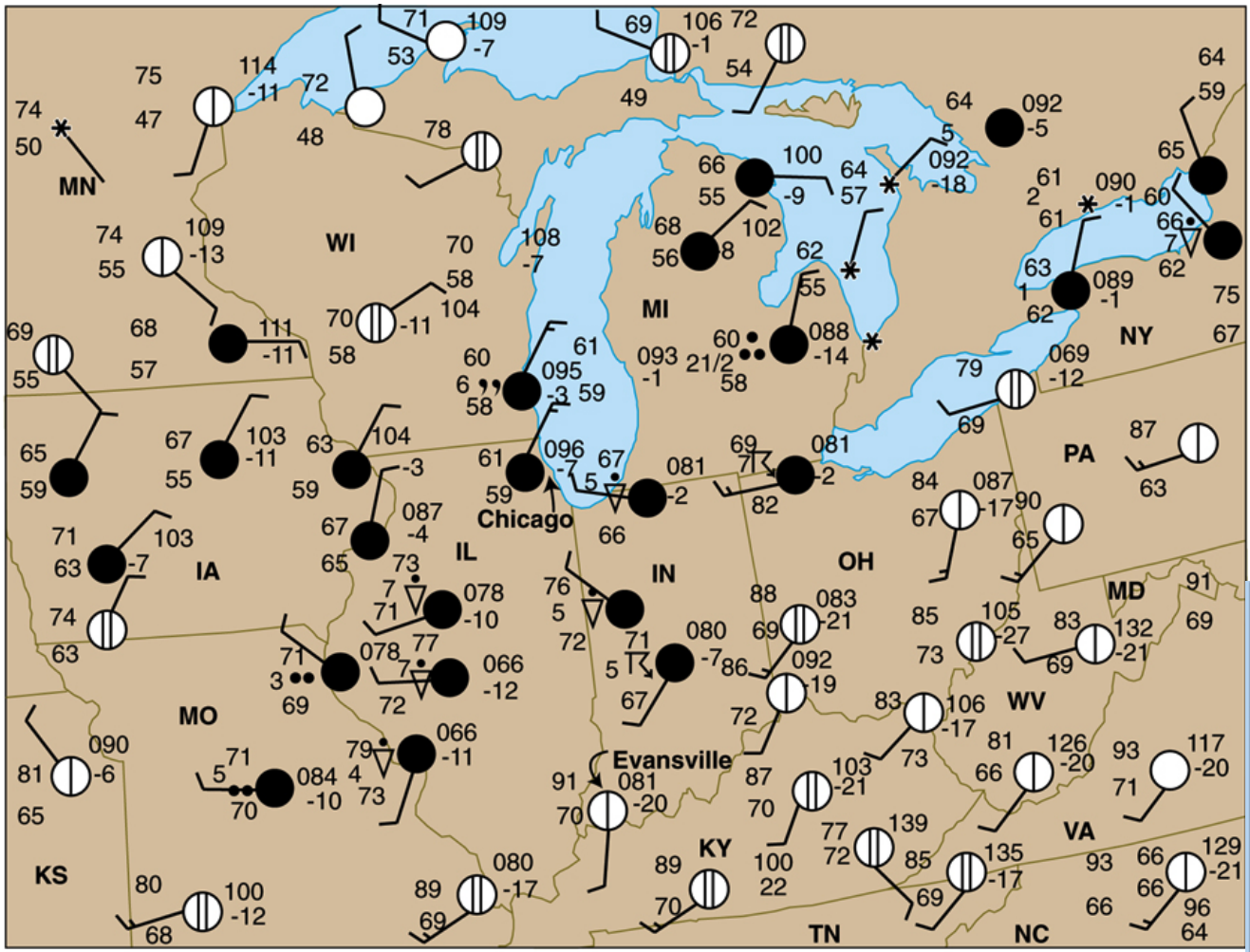
# Weather Map Plotting Symbols




- This is a summary of the most commonly occurring symbols on weather maps.

Graphic from *Meteorology* by Danielson, Levin and Abrams

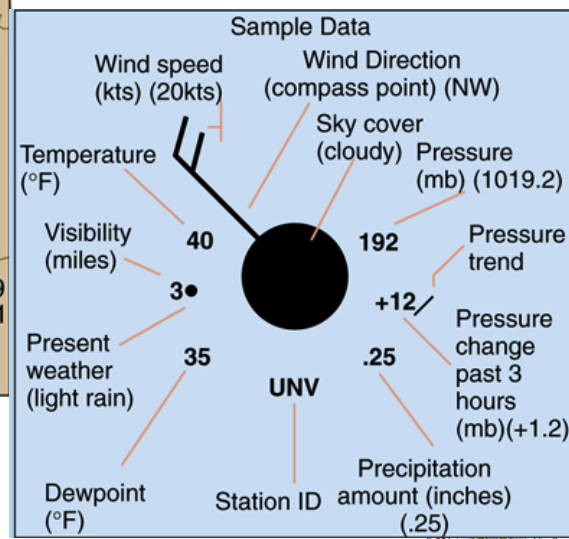
# Example Weather Map




HOURLY DATA
VALID 22Z 14-JUL-92

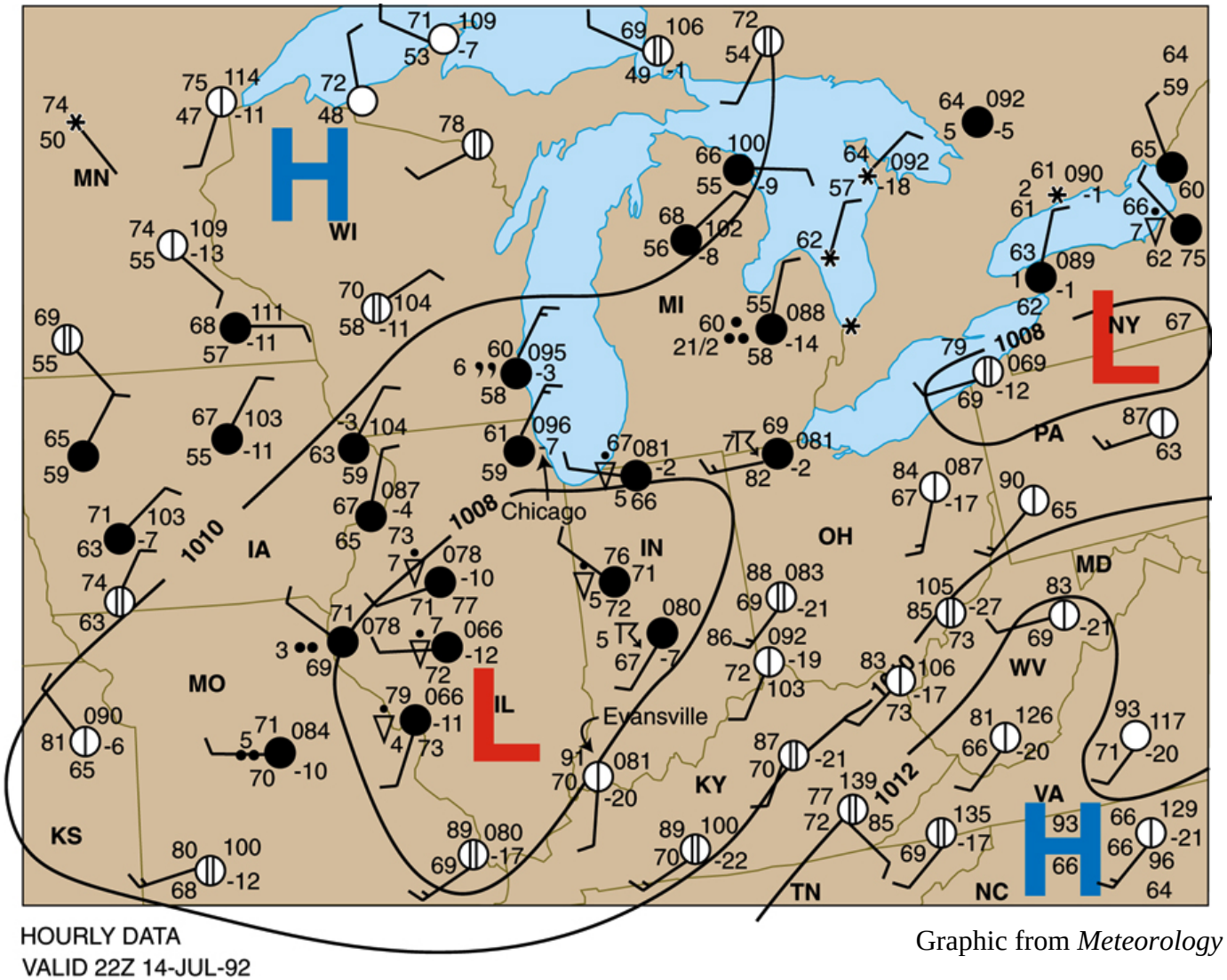
Look for

- areas of different cloud cover and precipitation,
- Areas of similar temperature (or boundaries of these areas)
- Changes in wind direction
- Changes in humidity




Graphics from *Meteorology* by Danielson, Levin and Abrams

# Surface Weather Map




**H** = High Pressure

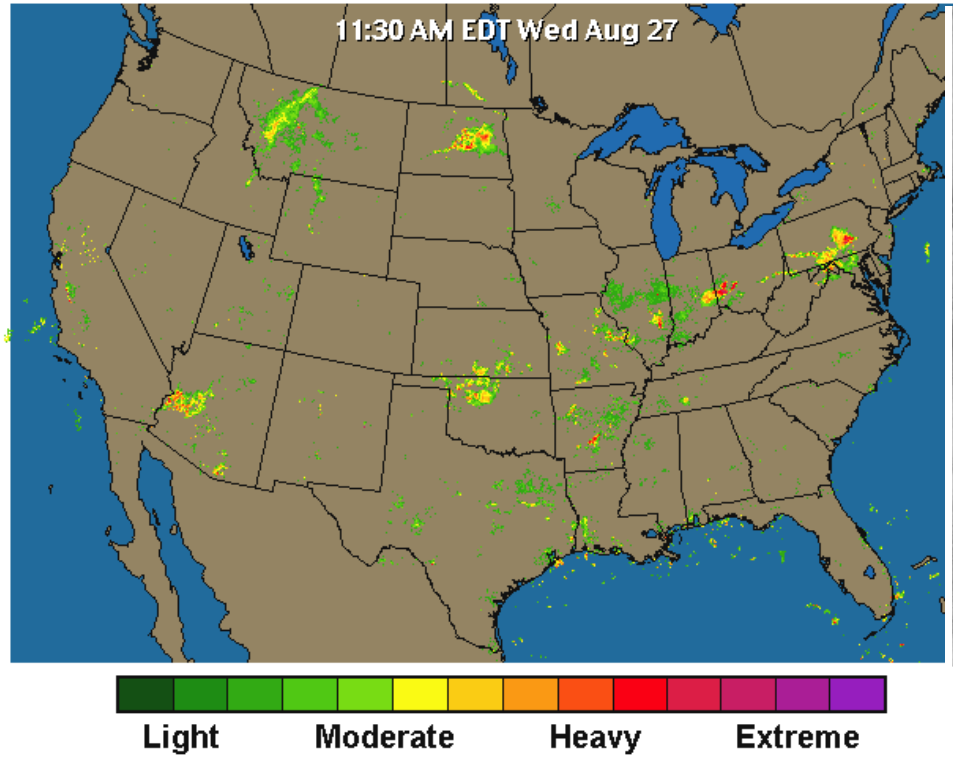
**L** = Low Pressure

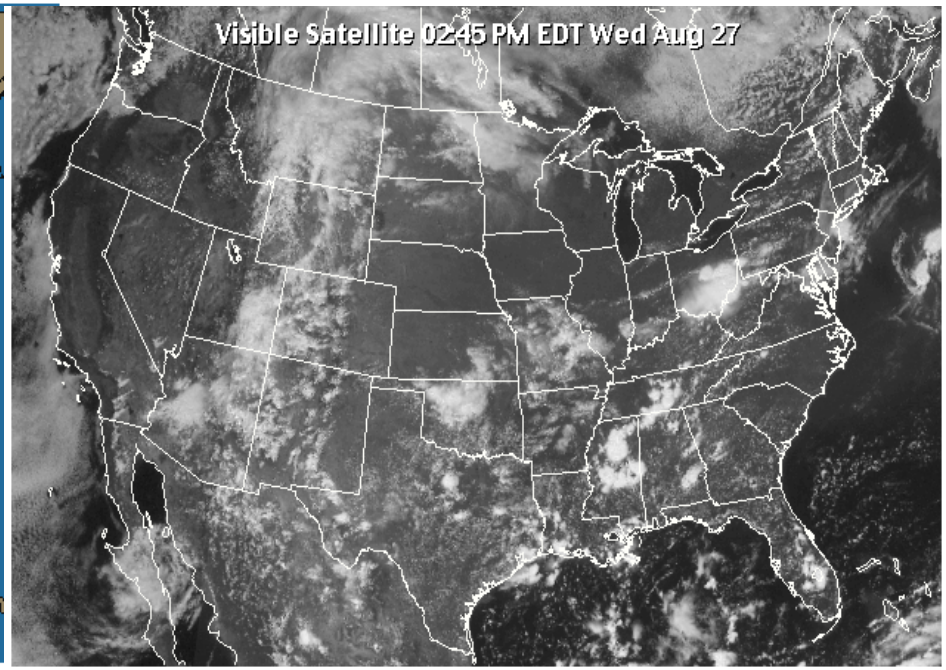
Solid Lines are isobars: lines of constant pressure.

Isobars circle around highs and lows. They do not pass through maximums or minimums in pressure.

Graphic from *Meteorology* by Danielson, Levin and Abrams

# Examples




- Examples are from the Weather Underground, Inc.